Available online at http://ijdea.srbiau.ac.ir

Int. J. Data Envelopment Analysis (ISSN 2345-458X)

Vol.8, No.3, Year 2020 Article ID IJDEA-00422, 19 pages
Research Article

International Journal of Data Envelopment Analysis

Science and Research Branch (IAU)

Imprecise Data Envelopment Analysis (IDEA) and its use in evaluating the performance of organizations based on the EFQM model

A. Soltani*

Department of industrial engineering, Islamic Azad University, Tonekabon branch.

Received 15 February 2020, Accepted 13 May 2020

Abstract

In this study a pattern has been proposed to evaluate efficiency of organizations in performing the European Foundation for Quality Management (EFQM) model, using Robust DEA with the following features:

- Performance evaluation of organizations is based on RADAR logic, a dynamic assessment framework and powerful management tool that provides a structured approach to questioning the performance of an organization, in the EFQM model.
- In this study, some data are imprecise in form of intervals with vague bounds.
- The performance evaluation based on the mathematical optimization rules has been replaced by the current multi-criteria evaluation approach.

Criteria have been reviewed based on RADAR logic, Analytical Hierarchy Process (AHP) method has been used to weight some indices and factor analysis has been used to find the more important criteria related to enablers. The contribution of this paper is threefold :(1) use of the factor analysis and the aggregation mechanism of the constructs to detect the major criteria in performing the EFQM model (2) using a robust optimization DEA model in which the output parameters are in form of intervals with imprecise bounds. (3) We use randomly a set of numbers generated for each input and output of DMUs to specify a range of Gamma in which the rankings of the DMUs occur with high probability and then compute the conformity of the rankings resulting from the mathematical model with reality.

Keywords: Evaluation, Interval DEA, RADAR logic, Robust DEA, uncertain data

---

*. Corresponding author: Email: alisollttani@gmail.com

1. Introduction

Today innovation and knowledge management are determining factors for success and continuity of organizations. Attentive the principle of continuous monitoring of processes and results and inspecting of problems and defects and taking action to eliminate them or modifying process are considered as requirements for continuous organizational improvements in Total Quality Management. Evaluation pattern of organizations, inspired of European Foundation Quality Management, have been designed and referred to a framework formed based on eight-dimensional criteria. Some, are enabler group and indicate type of activities of organization and the residual part of the results, specifying the demands that the organization must achieve them by performing enablers. It is obvious that success in improvement of efficiency and achieve the aims in EFQM model require reviewing the criteria and resolving their defects well suited to the aforementioned pattern as well as their generalization in all the levels involved. The proper assessment based on a scientific principle and method and present a suitable mechanism in this context can be a step to resolve some of the deficiencies mentioned above. Performance evaluation in the current approach based on RADAR logic has some fundamental problems:

- The criteria and their weights are selected based on unscientific views.
- The assessment process is based on a complex and unsuitable multi-criteria decision making which cannot be ensured.
- Integrating of assessments is based on unscientific views.

The present research intends to propose an approach to assess performance, using mathematical optimization, RDEA. (See figure1)

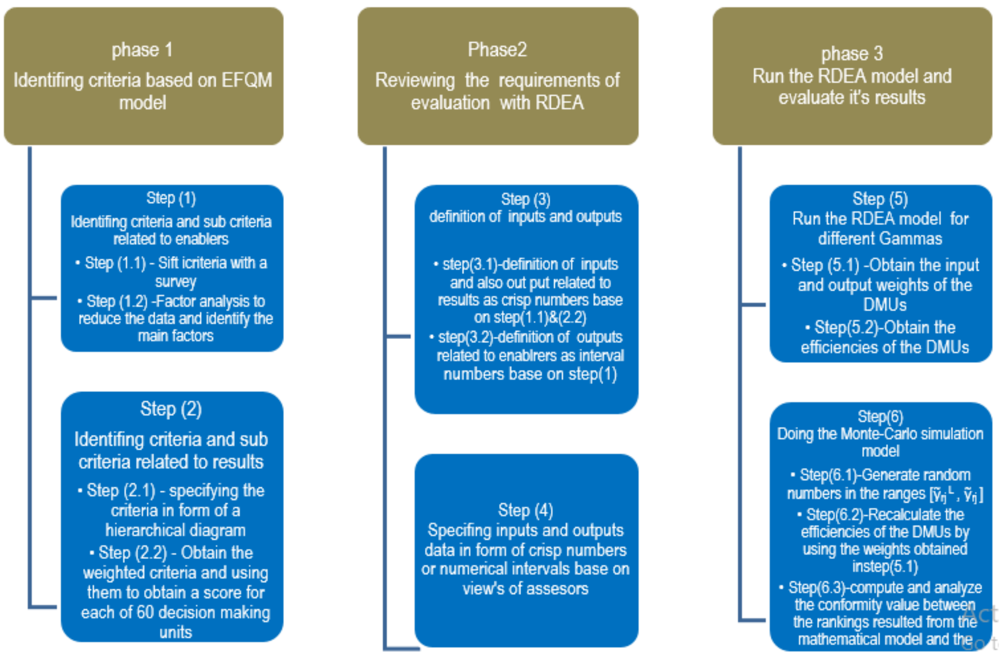

Figure 1- a schematic view to demonstrate the different stages of the research

This research has been conducted in five sections; in the first section, the literature review and related works on models for assessment of performance of organization based of EFQM model, use of AHP and DEA models and a variety of approaches proposed presented with uncertain data have been reviewed. In the second section, it has been discussed on research methodology. The criteria have been screened based on RADAR logic and then the criteria which are known with enabler criteria are summarized in 16 cases in five groups using exploratory factor analysis. In this section, Robust DEA has been introduced as an approach for presenting the problem of data uncertainty and how to use this method to evaluate performance of 48 organizations has been examined. In the third section, the proposed model is introduced and how to perform it is examined; in the fourth section the outcomes from use of RDEA method have been proposed to evaluate 48 organizations under evaluation in this research; ultimately in the last section, we summarize our conclusions and findings of research have been proposed.

2. Literature review

The terms "evaluation" and "assessment" and also the relation between EFQM measures and RADAR logic and also cognizance of the requirements for evaluation of culture and determination of maturity level in the context of EFQM excellence model" have been specified in several forms in literature review and theoretical background. In a research Seyed Amir Bolboli developed a new concept for efficient design of EFQM excellence model. This concept consists of three main parts: assessment of culture types in context of EFQM; assessment of maturity level; and design of EFQM measures based on RADAR logic. In his opinion, the findings were expected to reduce the effort for implementation of EFQM by designing tailored measures that fit to the existing culture and maturity level. The findings of this study were relevant to multinational large firms that deal with EFQM or similar excellence models. This paper presents a new concept for designing EFQM in the light of prevailing corporate culture and maturity level, which in one hand needs fewer resources and on the other hand it is more effective in implementation [1]. In another research, F.Semnani developed a model using accreditation standards, clinical governance and EFQM model of organization sublimity and the combination of these standards with balanced score card (BSC) model dimensions. The designed model was administered in Hasheminejad Hospital for 4 years, and the results related to the consecutive years were analyzed and compared. The model administration for 4 years in Hasheminejad Hospital indicated continuous improvement of hospital performance and the success of the presented model [2]. Deise Graziele Dickel and Gilnei Luiz de Moura, in another study developed a model to measure organizational performance with a focus on knowledge management and innovation management. To be able to do that, they used a quantitative research study, characterized as a multi-case study applied to three companies in the metal-mechanic sector in southern Brazil. The methodology used the assumptions of well-known methods such as the Key Performance Indicators, the Swing Weighting and Simple Attribute Rating Technique. The results, according to the authors could be seen that the proposed model can be an effective tool for assessing organizational performance and that, in its application, the surveyed organizations could already identify their main weaknesses and use the results reported to improve its management [3]. In another study Nelly.et.al. has defined performance measurement as the process of quantifying the efficiency and effectiveness of activities of activities [4]. According to the explanation by Simons, performance assessment system has been defined with four major aims including transfer of information, focus on official affairs and procedures, and design for use of managers, and supervision on maintenance or modification of organizational activity patterns [5]. In another definition, performance evaluation is defined as a systematic process which plans and organizes the tasks and expectations, monitors the performance constantly, creates the implementation capacity, ranks performance periodically and grants reward to suitable performance [6]. Up to now, many studies have been produced about the context of design of performance evaluation systems. Some, resulted in proposal of various performance evaluation systems. Among these performance evaluation models, it can refer to Sink and Tuttle Model, performance matrix, the model of results and determinants, the performance pyramid, Balanced Scorecard, stakeholder analysis, and the business excellence model. [7] These studies have been organized via different approaches and various techniques, attempted to introduce a pattern for performance evaluation of this system. In a study by Jaffar pour et al., a framework has been proposed to evaluate performance of this system using DEA [8]. In another study, CIPP model has been proposed to evaluate performance of work groups in medical science university of Isfahan [9]. In an article entitled "assurance region" a method was used to allocate weight to input and output criteria to select the best place for High-energy physics laboratory. In this research, it was indicated that some inputs or outputs are poorer than rest of efficient DMUs in some DMUs because numerous zeros, raised in optimal weight (u_r*, v_i*) in DEA models, thus this defect in DEA method is resolved through invention of assurance region method [10]. Another method which was proposed refers to the method "Cone ratio envelopment" used by Charles and his colleagues. In another study by Brackets et al. Cone ratio envelopment has been used to evaluate performance of banks under the conditions that uncertain aid grant was considered for risk and similar factors [11]. In 1998, assurance region method was proposed for transfer of capital in Japan in form of a plan. In this plan, the criteria such as distance from Tokyo, access to an international airport and several other criteria were considered, that the scores were specified for each place. The assessors considered a weight for each of criteria based on Analytic Hierarchy Process and ultimately obtained an assurance region for each weight through calculating ratio of weights specified by different assessors [12]. Due to extensive applications of DEA model in the real world problems since the studies by Charnes, Cooper and Rhodes, huge efforts have been made to expand DEA models. Encounter with uncertain data has been regarded as an issue drawn into attention by Despotis, D. K., & Smirlis (2002) & Cooper and Park (1999). In ordinary DEA, all the data are assumed as certain numerical values. Yet, the observed values of inputs and outputs in the real world problems are often uncertain. Uncertain data in DEA models have been examined in the literature in different forms. Some researchers have suggested Fuzzy data envelopment analysis and interval data envelopment analysis in encounter with uncertain data. In more recent period, uncertain data have been expressed by means of two approaches. Interval data envelopment analysis was proposed for the first time by Cooper, W. W., Park, K. S., & Yu, G.(1999) and fuzzy data envelopment analysis was proposed for the first time by Sengupta. Cooper, W. W., Park, K. S., & Yu, G. (1999) have extended an interval approach which allows using a mix of uncertain and certain data by means of transformation of DEA model to an ordinary linear planning form. Assessment of lower and upper limits of DMU efficiencies has been regarded as one of the problems in interval approach [13]. Despite this problem, some researchers have proposed a variety of interval approaches [14].In another article, Guo & Tanaka proposed an approach based on $\propto -$cut which changes fuzzy DEA model to a bi-level linear planning model. [15] Nasabadi et al. indicated that their model cannot be common as a proposed model, having an optimal response under limited conditions. Despite the studies by Guo & Tanaka (2008), Nasabadi. et al. used the proposed fuzzy DEA model by Guo & Tanaka and introduced a fuzzy integrative framework to integrate fuzzy values with multiple states [16]. In addition, Guo used the model proposed by Guo & Tanaka (2001-2008) in a case study for localization problem of a restaurant in China [17]. Kao & Liu (2000) proposed a technique which transforms fuzzy DEA model to a family of certain DEA models by use of $\propto -$cut approach. In another research, Azadeh et al. used fuzzy DEA model to specify relative efficiency of existing units in the electricity generation sectors in Iran. In this research, using data in fuzzy form and creating CCR fuzzy model, it has been transformed to a model with interval data via a model based on a-cut [18]. In another research by Shokouhi et al., an approach based on Robust Data Envelopment Analysis was proposed in which the input and output parameters are restricted to this point that they must be considered in an indefinite set with additional restrictions based on the worst corresponding response with uncertain set [19]. In a study by Nikfarjam et al. [20], a new dynamic DEA approach is proposed which is capable of evaluating the suppliers in consecutive periods based on their inputs, outputs, and the relationships between the periods classified as desirable relationships, undesirable relationships, and free relationships with positive and negative natures. To this aim various social, economic, and environmental criteria are taken into account. A new method for constructing an ideal decision-making unit (DMU) is proposed in this paper which difers from the existing ones in the literature according to its capability of considering periods with unit efficiencies which do not necessarily belong to a unique DMU. Furthermore, the new ideal DMU has the required ability to rank the suppliers with the same efficiency ratio. In the concerned problem, the supplier that has unit efficiency in each period is selected to construct an ideal supplier. In another study by Shakouri et al [21]. To measure the performance of a commercial bank uses a more robust system for estimating performance in conditions of uncertainty.in this research, the p-robust DEA model is introduced and then calculated the priority weights of each scenario for CCR DEA output oriented method. To compute the priority weights of criteria in discrete scenarios, the analytical hierarchy analysis process (AHP) is used. To tackle the uncertainty of experts' opinion, a synthetic technique is applied based on both robust and stochastic optimizations. In the sequel, stochastic p-robust models are proposed for the estimation of efficiency, with particular attention being paid to DEA models

3. Research methodology

The methodology used in this evaluation has been taken from the applied verities of the subject and is based on fundamental Concepts which underpin the EFQM Model and RADAR evaluation logic. Two categories of input and output data are detected in evaluating of organization's performance based on the proposed criteria grounded on excellence approach. Then, efficiency of organizations is assessed using data envelopment analysis. Since the appraisal criteria have been qualitative, the data related to these criteria have been given in form of interval value. In this research, the approaches are examined which cognizes, in DEA, with imprecise data. Since scoring is made by different assessors, it is clear that we deal with a type of data, for each input or output, in form of interval that their limits are imprecise. The current model of performance assessment of organizations is based on a form of multi-criteria decision making, in which some scores have been determined based on experts' view for the criteria and sub-criteria. It seems that such assessment model has huge problems in validity and reliability despite its simplicity. The problems include Incomplete and ambiguous evaluation indices, lack of the criteria which ensure alignment between these assessments, duality of criteria from quantitative and qualitative perspectives, how to score them, ignorance of difference between organizations in terms of their size, organizational structure and missions. The criteria of model and the scores allocated in the current system are as follow:

Table 1, Criteria and scores related to each of them in the current assessment system

<table>
<tr><td rowspan="3">Leadership (10%)</td><td>People (10%)</td><td rowspan="3">Processes, Products & Services (10%)</td><td>People Results (10%)</td><td rowspan="3">Key Results (15%)</td></tr>
<tr><td>Strategy (10%)</td><td>Customer Results (15%)</td></tr>
<tr><td>Partnership & Resources (10%)</td><td>Society Results (10%)</td></tr>
</table>

In this research, several intervals are acquired for each input or output that must be entered into the DEA model. In the first section of this research, all the criteria and sub-criteria are listed and categorized based on RADAR logic in EFQM model. In this method, criteria related to the enablers and also people, customer, and society results are qualitative and the criteria related to the key results are quantitative. These criteria were examined and summarized via two separate approaches. In both approaches, point of view of the experts and specialists on evaluating performance was considered as the basis for decision making. In this research, the statistical population consists of the experts in over 10 organizations. To examine the criteria in the first group, two stages are pursued. The first stage-significance of criteria was put into question via Likert scale in a pooling and the insignificant factors were omitted. The second stage-the remaining criteria from the previous stage were categorized in a way that they get close to each other in terms of subject and the number of criteria in each category to pave the way for use of factor analysis

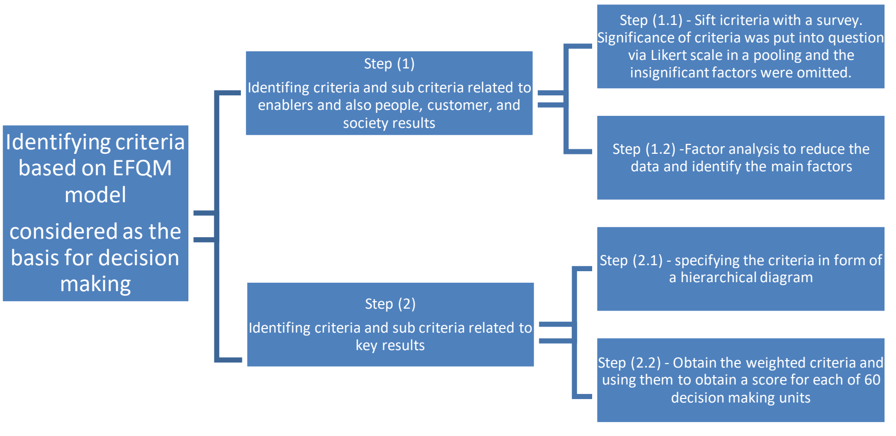

Figure 1- the steps to identify the criteria and sub-criteria to evaluate performance in implementing EFQM model

Factor analysis:

Factor analysis explain the expansion of analysis of main components. In these methods, the internal correlation between criteria is clarified via covariance matrix approximation and detect the main criteria. In this research, initially, all criteria were reviewed based on RADAR logic and screened based on experts' views via questionnaires. Then in order to reduction of the number of criteria, exploratory factor analysis has been used and then the obtained results have been examined via confirmatory factor analysis method. Again, after the factor analysis, the clustering of the groups were done with the opinion of experts. In this research, Cronbach's alpha has been used to determine reliability of responses and, software *SPSS has been used to make* factor *analysis.* (table 2)

Table 2, Extraction of factors based on factor analysis method

Evaluation areas	Number of sub-factors based on the logic of RADAR evaluation	Acronyms for sub-factors based on exploratory and confirmatory factor analysis and then combining the clusters obtained based on experts' views	Definitions of factors extracted from factor analysis	Acronyms for Factors
First area (Leadership)	Includes 34 sub-factors (X_1^1 to X_1^{34})	$Y_1^1, Y_1^2, Y_1^3, Y_1^4, Y_1^5, Y_1^6$	Leaders are role models of a culture of Excellence	Factor $_{11}$ (Y_1)
		$Y_2^1, Y_2^2, Y_2^3, Y_2^4, Y_2^5, Y_2^6, Y_2^7, Y_2^8$	Leaders are involved in ensuring the organization's management system and also involved with customers, parents and representatives of society.	Factor $_{12}$ (Y_2)
		$Y_3^1, Y_3^2, Y_3^3, Y_3^4, Y_3^5, Y_3^6, Y_3^7, Y_3^8, Y_3^9, Y_3^{10}$	Leaders identify and champion organizational change	Factor $_{13}$ (Y_3)
Second area (Policy & Strategy)	Includes 26 sub-factors (X_2^1 to X_1^{26})	$Y_4^1, Y_4^2, Y_4^3, Y_4^4, Y_4^5, Y_4^6, Y_4^7, Y_4^8, Y_4^9, Y_4^{10}, Y_4^{11}, Y_4^{12}$	Developing ,reviewing and updating policy and strategy	Factor $_{21}$ (Y_4)
		$Y_5^1, Y_5^2, Y_5^3, Y_5^4, Y_5^5, Y_5^6, Y_5^7, Y_5^8, Y_5^9$	Launching policies and Aligning , prioritizing , agreeing , communicating plans and targets	Factor $_{22}$ (Y_5)
Third area (Human Resource)	Includes 27 sub-factors (X_3^1 to X_3^{27})	$Y_6^1, Y_6^2, Y_6^3, Y_6^4, Y_6^5, Y_6^6, Y_6^7, Y_6^8, Y_6^9, Y_6^{10}, Y_6^{11}, Y_6^{12}$	People resources are planned, managed and improved and their competencies are identified, developed and sustained.	Factor $_{31}$ (Y_6)
		$Y_7^1, Y_7^2, Y_7^3, Y_7^4, Y_7^5$	People are involved and empowered	Factor $_{32}$ (Y_7)
		$Y_8^1, Y_8^2, Y_8^3, Y_8^4, Y_8^5, Y_8^6$	People and rewarded, recognized and cared for	Factor $_{32}$ (Y_8)
Forth area (Partnership & Resource)	Includes ٣٦ sub-factors (X_4^1 to X_4^{36})	$Y_{٩}^1, Y_{٩}^2, Y_{٩}^3, Y_{٩}^4, Y_{٩}^5$	External partnerships are managed	Factor $_{41}$ (Y_9)
		$Y_{١٠}^1, Y_{١٠}^2, Y_{١٠}^3, Y_{١٠}^4, Y_{١٠}^5, Y_{١٠}^6, Y_{١٠}^7, Y_{١٠}^8, Y_{١٠}^9, Y_{١٠}^{١٠}, Y_{١٠}^{11}, Y_{١٠}^{12},$	Finances, Buildings, Equipment and Materials are managed	Factor $_{42}$ (Y_{10})
		$Y_{١١}^1, Y_{١١}^2, Y_{١١}^3, Y_{١١}^4, Y_{١١}^5, Y_{١١}^6, Y_{١١}^7, Y_{١١}^8$	Technology, Information and knowledge are managed	Factor $_{43}$ (Y_{11})
Fifth area (processes)	Includes 29 sub-factors (X_5^1 to X_5^{29})	$Y_{١2}^1, Y_{١2}^2, Y_{١2}^3, Y_{١2}^4, Y_{١2}^5, Y_{١2}^6, Y_{١2}^7, Y_{١2}^8, Y_{١2}^9, Y_{١2}^{١٠}, Y_{١2}^{11}, Y_{١2}^{12},$	Processes are systematically designed and improved and developed, as needed using innovation in order to fully satisfy and generate increasing value for customers and other stakeholders	Factor $_{51}$ (Y_{12})
		$Y_{١3}^1, Y_{١3}^2, Y_{١3}^3, Y_{13}^4, Y_{١3}^5, Y_{١3}^6, Y_{١3}^7, Y_{13}^8, Y_{13}^9$	Products and Services are produced, delivered and serviced and customer relationships are managed and enhanced	Factor$_{52}$ (Y_{13})
Sixth, seventh &eighth areas(Result)	Includes 6 sub-factors(21items)	$Y_{١4}^1$(includes 4 items), $Y_{١4}^2$(includes 4items)	Customer Result	Factor $_{61}$ (Y_{14})
		$Y_{١5}^1$(includes 2 items), $Y_{١5}^2$(includes 4 items)	Human resource Result	Factor $_{62}$ (Y_{15})
		$Y_{١6}^1$(includes 4 items), $Y_{١6}^2$(includes 3 items)	Society Result	Factor $_{63}$ (Y_{16})

AHP Model:

The criteria related to the key results are another important section of the criteria of the units under study drawn into attention. In this research, the indices which reflect success in achievement of eligible results are specified in form of a hierarchical diagram. Using the obtained weighted criteria for each of 48 decision making units under study in this research, a score has been obtained and used as an output in the data envelopment analysis.

Robust formulation for linear planning problems

Consider linear optimization problem as follow:

Maximize c' x

Subject to Ax ≤ b (١)

l ≤x ≤ u

Consider i^{th} row in matrix A and consider *Ji* as set of coefficients in i^{th} row which have uncertainty. Any input $a_{ij}\ ;\ j \in J_i$ is modeled as a random symmetric and bounded variable ($\tilde{a}_{ij}$), proposed with $[a_{ij} – \hat{a}_{ij}\ ,\ a_{ij} + \hat{a}_{ij}\ ]$. Corresponding to each uncertain $\tilde{a}_{ij}$ data, a random variable $\eta_{ij} = (\tilde{a}_{ij} - a_{ij}) / \hat{a}_{ij}$ is defined which follows an unknown distribution and given with the values in interval [-1, 1]. In this regards, robust formulation will be as follow:

Maximize c' x

subject to (٢)

$$\sum_j a_{ij}\, x_j + \sum_{j\epsilon J_i} \hat{a}_{ij}\, y_j \le b_i$$

$$-y_j \le x_j \le y_j$$

$$l \le x \le u$$

$$y \ge 0$$

Assume x^* as optimal response in above formulation, there will be $y_j = |x^*_j|$ under optimal conditions, thus:

$$\sum_j a_{ij} x^*_j + \sum_{j\epsilon J_i} \hat{a}_{ij}\, |x^*_j| \le b_i \quad \forall i$$

Now, we will show that this response will be possible per each real value $\tilde{a}_{ij}$ of indefinite data.

$\sum_j \tilde{a}_{ij}\, x^*_j = \sum_j\ a_{ij}\, x^*_j + \sum_{j\epsilon J_i} \hat{a}_{ij}\, \eta_{ij}\, x^*_j \le \sum_j a_{ij} x_j + \sum_{j\epsilon J_i} \hat{a}_{ij}\, |x^*_j| \le b_i \qquad \forall i$

It should be noted that $\eta_{ij} = (\tilde{a}_{ij} - a_{ij}) / \hat{a}_{ij}$ and thus $a_{ij} + \eta_{ij}\, \hat{a}_{ij} = \tilde{a}_{ij}$ and ultimately:

$\sum_j \tilde{a}_{ij}\, x^*_j = \sum_j\ \eta_{ij}\, \hat{a}_{ij}\, x^*_j + \sum_j\ a_{ij}\, x^*_j$

Therefore:

$\sum_j \tilde{a}_{ij}\, x^*_j = \sum_{j\epsilon J_i}\ \eta_{ij}\, \hat{a}_{ij}\, x^*_j + \sum_j\ a_{ij}\, x^*_j$

In row above, η_{ij} equals to 0 per *js* that do not belong to J_i, thus $j \epsilon J_i$ has been substituted. $\sum_{j\epsilon J_i} \hat{a}_{ij}\, |\ x_j\ |$ defines the essential protection level for that restriction at interval $\sum_j a_{ij}\, x^*_j$ and b_i .

Bertsimas and Sim model

In this model, a robust formulation is proposed which is linear, enabled to resist against uncertain parameters in the model under discussion regardless of a significant effect on objective function. Formulation of Bertsimas and Sim model is as follow: Assume i^{th} restriction of nominal problem as $a_i^{'} X \le b_i$. Assume J_i as the set of uncertain coefficients and assume these coefficients($\tilde{a}_{ij}$; $j \in J_i$) given with values in $[a_{ij} – \hat{a}_{ij}\ ,\ a_{ij} + \hat{a}_{ij}\ ]$ which have symmetric distribution with mean equal to nominal value(a_{ij}). A parameter (Γ_i) which is not integer is introduced per i which is given a value in $[0, |J_i|]$. role of this parameter is to regulate robustness of Bertsimas's method against conservatism level of response. In other words, it is unlikely intuition which changes all a_{ij} as much as possible. We can achieve our aim in encounter with all the states in which the coefficients change and a coefficient a_{it} changes to the size ($\Gamma_i - [\Gamma_i]$), i.e. the only sub-set of the coefficients changes in a way with negative effect on response. In addition, robust response will be likely with high probability for the changes in more than $[\Gamma_i]$ variable. The result will be formulation of problem below which is a non-linear problem:

$$Max\ \acute{C}\ X \qquad (٣)$$

$$s.t.\ \sum_j a_{ij}\, x_j + \max_{C_i} \{ \sum_{j\epsilon S_i}\ \alpha\hat{}_{ij}\ y_j + (\Gamma_i - \lceil \Gamma_i \rceil)\, \alpha\hat{}_{it_i} y_{it_i} \} \le b_i \ ,\ \forall i$$

$$-y_j \le x_j \le y_j \quad ,\ \forall j$$

$$L \le X \le U$$

$$Y \ge 0$$

In which: $C_i = \{S_i \cup \{t_i\} | S_i \subseteq J_i\, , |S_i| = \Gamma_i, t_i \epsilon J_i - S_i\}$.

If Γ_i is selected as integer, ith restriction will be as follow:

$$\beta_i(x, \Gamma_i) = \max_{Ci} \{ \sum_{j\epsilon S_i}\ \alpha\hat{}_{ij}\ |x_j| \}\ ,$$

$$C_i = \{S_i\ | S_i \subseteq J_i\, , |S_i| = \Gamma_i\}$$

When Γ_i = ٠, there will be $\beta_i\,(x, \Gamma_i) = 0$ and the restriction will be corresponding to nominal problem. Further if $\Gamma_i = |J_i|$, there will be swister's method. Therefore, there will be the possibility to regulate robustness degree against different levels of conservatism in the response by change of this parameter in interval with two above values. Theorem below is required to rewrite this model in form of a linear model. Theorem 1: vector x^* has been given.

$$\beta_i(x^*, \Gamma_i) = \max_{Ci}\{ \sum_{j\epsilon S_i} \alpha^{\wedge}_{ij} |x^*_j| + (\Gamma_i - \lceil\Gamma_i\rceil)\, \alpha^{\wedge}_{it_i}|x^*_j| \}$$

In which:

$$C_i = \{S_i \cup \{t_i\} | S_i \subseteq J_i, |S_i| = \Gamma_i, t_i \epsilon J_i - S_i\}$$

<u>Conservative</u> function related to the ith restriction above is equivalent to the objective function of the linear planning problem below:

$$\beta_i(x^*, \Gamma_i) = \max \sum_{j\epsilon J_i} \alpha^{\wedge}_{ij} |x^*_j| z_{ij} \quad \text{s.t.} \quad \sum_{j\epsilon J_i} z_{ij} \le \Gamma_i, \quad 0 \le z_{ij} \le 1 \ (j\epsilon J_i) \qquad (٤)$$

Now non-linear model related to Bertsimas's method can be represented as follow in form of linear formulation.

$$\begin{aligned} & Max\ \acute{C}X \\ & S.t. \qquad (٥) \\ & \sum_j a_{ij} x_j + z_i \Gamma_i + \sum_{j\epsilon S_i} p_{ij} \le b_i, \quad \forall i \\ & z_i + p_{ij} \ge \alpha^{\wedge}_{ij} y_j, \quad \forall i.j\epsilon J_i \\ & -y_j \le x_j \le y_j, \quad \forall j \\ & l_j \le x_j \le u_j, \quad \forall j \\ & p_{ij} \ge 0, \quad \forall i.j\epsilon J_i \\ & y_j \ge 0, \quad \forall j \\ & z_i \ge 0, \quad \forall i \end{aligned}$$

By considering structure of robust formulation, it is clear that [Γ_i] with coefficients a_{ij} changes per its bounds and a coefficient with size (Γ_i – [Γ_i]) $\hat{a}_{it}$ changes, thus the problem remains unresolved. By proving the theorems below, it can indicate that the robust model is possible with high probability under uncertain data. Parameter Γ_i regulates the balance between the probability for negation and result of objective function of nominal problem, called with robustness.

Theorem 2: assume x^* as optimal response in formulation above and S^*_i and t^*_I as the indices corresponding with the maximum obtained value for β_i (x^*, Γ_i), here there will be:

a-the probability for negation of i[th] restriction is as follow:

$$P\left(\sum_j \tilde{a}_{ij} x_j > b_i\right) \le P\left(\sum_{j\epsilon J_i} \gamma_{ij}\eta_{ij} \ge \Gamma_i\right)$$

$$\gamma_{ij} = \begin{cases} 1, & \text{if } j\epsilon S^*_i \\ \alpha^{\wedge}_{ij} |x^*_j| / \alpha^{\wedge}_{ir^*} |x^*_{r^*}|, & \text{if } j\epsilon J_i - S^*_i \end{cases}$$

$$r^* = \arg\min_r \alpha^{\wedge}_{ir} |x^*_r|, \quad r \in S^*_i \cup \{t^*_i\}$$

$$P\left(\sum_{j\epsilon J_i} \gamma_{ij}\eta_{ij} \ge \Gamma_i\right) \le \exp\left(-\frac{\Gamma_i^2}{2|J_i|}\right)$$

b-values γ_{ij} come true for all the values $j \in J_i - S_i$ in $\gamma_{ij} \le 1$.

Theorem 3: if $j \in J_i$ and η_{ij} are assumed as random symmetric and independent variables distributed in [-1,1].

Now, we present the mathematical details of the robust DEA model proposed in this paper. Let us consider the DMUj and assume that J_j is the index set of the imprecise output values. Let us further consider parameter Γ_j, not necessarily integer, that assume value in the bounded interval [0 , $|J_j|$], where, $|J_j|$ is the cardinal of J_j. The role of this parameter is to adjust the robustness of the proposed model against the conservatism level of the solution. Indeed, it is unlikely that all of the imprecise outputs will change simultaneously. In other words, we stipulate that only a subset of the output data should change to affect the solution that was defined by Bertsimas and Sim (2004). Then, considering the robust optimization approach, we change it as follows:

$$\begin{aligned} & \text{Max } E_O = \sum_{r=1}^{s} u_r y_{ro} - \beta_o(y, \Gamma_o) \\ & \text{s.t.} \qquad (٦) \\ & \sum_{i=1}^{m} v_i x_{ij} + \beta_o(y, \Gamma_o) = 1 \\ & \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + \beta_j(y, \Gamma_j) \le 0, \ (j \ne o) \\ & E_O \le 1 \\ & u_r, v_i \ge \varepsilon \end{aligned}$$

We use the robust optimization approach to introduce $\beta_j(y, \Gamma_j)$ to move from the optimistic to the pessimistic viewpoint. In other words, these variables protect the constraints against data uncertainty and keep them feasible:

$$\beta_j(y, \Gamma_j) = \max_{C_j}\left\{ \sum_{r\epsilon S_j} u_r\, \hat{y}_{rj} + (\Gamma j - \lceil \Gamma j \rceil)\, \hat{y}_{rt_j} \right\},$$

$$C_j = \{S_j \cup \{t_j\} | S_j \subseteq J_j, |S_j| = \Gamma j, t_j \epsilon J_j - S_j\}$$

Now,with regard to our approach, the defined robust model obtains up limit of efficiency for each of organizations. The difference is that, according to the approach mentioned, here all units are considered in the best condition. if we consider, $y_{ro} = y_{ro}^{U}$, $y_{rj} = y_{rj}^{U}$, $\hat{y}_{rj} = \hat{y}_{rj}^{U}$ then model above is solved by considering the following form which is used to calculate efficiency and rank of DMUs:

$$\max_{u_r, v_i} \quad E_o = \sum_{r=1}^{s} u_r\, y_{ro}^{U} - p_o \Gamma_j - \sum_{r=1}^{s} q_{ro}$$

$$\sum_{i=1}^{m} v_i\, x_{io} = 1 \qquad (7)$$

$$\sum_{i=1}^{m} v_i\, x_{ij} - \sum_{r=1}^{s} u_r\, y_{rj}^{U} - p_j \Gamma_j - \sum_{r=1}^{s} q_{rj} \geq 0$$

$$p_j + q_{rj} \geq u_r \hat{y}_{rj}^{U}$$

$$E_o \leq 1$$

$$p_j, q_{rj} \geq 0$$

$$u_r, v_i \geq \varepsilon \quad (r = 1,2, \dots, s\,, i = 1,2, \dots, m)$$

We should note that, the level of conservatism in the output data have to be discretely determined by the decision maker (or expert). In this research, we assumed that all Γ_j are equal to Γ. As a result, we formulate the following non-linear model:

$$\max_{u_r, v_i} \quad E_o = \sum_{r=1}^{s} u_r\, y_{ro}^{U} - p_o \Gamma - \sum_{r=1}^{s} q_{ro}$$

$$\sum_{i=1}^{m} v_i\, x_{io} = 1 \qquad (8)$$

$$\sum_{i=1}^{m} v_i\, x_{ij} - \sum_{r=1}^{s} u_r\, y_{rj}^{U} - p_j \Gamma - \sum_{r=1}^{s} q_{rj} \geq 0$$

$$p_j + q_{rj} \geq u_r \hat{y}_{rj}^{U}$$

$$E_o \leq 1$$

$$p_j, q_{rj} \geq 0$$

$$u_r, v_i \geq \varepsilon \quad (r = 1,2, \dots, s\,, i = 1,2, \dots, m)$$

4. The proposed model and how to perform it

With regard to above, there are 48 DMUs under evaluation. Inputs for jth DMU have been showed with X_{1j} (budget), X_{2j} (number of stuffs) and X_{3j} (educated level) and 16 outputs related to the uncertain scores have been showed with $[\tilde{Y}_{ij}^{L}, \tilde{Y}_{ij}^{U}]$. The last output represents score of results of performance which is calculated via hierarchical method in form of a certain value. This model can be explained using EFQM model. In assessments, the elements contributed in better performance of this system in the organizations are taken into consideration in addition to the criteria considered with EFQM model. In the proposed model in this research, the weights corresponding to advantages of each of organizations mentioned as the features of DEA method are used instead of use of fixed scores for each group of defined factors and criteria which is mentioned as the most important fault of the current assessment system. The criteria related to three above enablers are assessed by different experts. Each of above criteria includes several sub-criteria to which a value ranging from 0 to 100 is given for trust on assessments. Then the mentioned values are integrated and combined with view of other experts, e.g. assume five persons engage in assessment of j^{th} unit (DMUj), these five persons represent their views considering the defined scale in the diagram for $Factor_{41}$ or (Y_9), which defines managing external partnerships.

Table 3, how to get output data base of views of experts, in proposed model

assessors	Y_9^1	Y_9^2	Y_9^3	Y_9^4	Y_9^5	Y_9^6	average
A	[75,90]	[75,90]	[40,55]	[75,80]	[60,80]	[50,65]	[62,77]
B	[55,70]	[55,75]	[65,75]	[50,60]	[45,55]	[65,75]	[56,68]
C	[70,80]	[75,85]	[70,85]	[70,80]	[60,80]	[55,75]	[67,81]
D	[50,65]	[50,60]	[45,55]	[40,55]	[60,65]	[55,60]	[50,60]
E	[50,55]	[50,60]	[80,90]	[50,65]	[50,70]	[80,95]	[60,72]
average							[59,72]

With regard to the table above; $[y_{ij}^L , y_{ij}^U]$ = [59, 72].
It can consider the obtained result in form of an interval with uncertain bounds $[\tilde{y}_{rj}^{L}, \tilde{y}_{rj}^{U}]$, in which:
$\tilde{y}_{rj}^{L} = y_{rj}^{L} \pm \mathring{y}_{rj}^{L}$, $\tilde{y}_{rj}^{U} = y_{rj}^{U} \pm \mathring{y}_{rj}^{U}$
In terms above, y_{ij}^{L} and y_{ij}^{U} are called with nominal values in uncertain bounds in above interval and $\mathring{y}_{ij}^{L}$ and $\mathring{y}_{ij}^{U}$ are considered as their range of variations:
y_{ij}^{L}: mean of low bounds of assessors' views/number of assessors
y_{ij}^{U}: mean of up bounds of assessors' views/number of assessors
The probability for negation of restrictions in output-based CCR model by considering different values for Γ is shown with instance, e.g. it equals to 0.42, 0.32, 0.22 and 0.13 for values 5, 6, 7 and 8. Therefore, it seems that Γ_j =7 can be a suitable value for this problem.

$$\Gamma_j = 7 \rightarrow \exp(-{\Gamma_j^2}/{|J_j|}) = \exp(-1.5) = .22$$

5- Research findings and results
Now we follow our approach to solving model (٨). this model is solved for different combinations of Γs, and values of weights and rankings for each DMU are saved by using the obtained values for E. The DMU efficiencies obtained for each Gamma through the RDEA model may result in different rankings of the DMUs. (See table)

Table 4: the efficiency of some DMUs for different Gamma levels

Gamma:	0	1	2	4	6	8	10	12	14	15	16
DMU3	1/0000	0/9900	0/9870	0/9700	0/9616	0/9612	0/9611	0/9611	0/9610	0/9610	0/9610
DMU7	0/9924	0/9424	0/9224	0/9145	0/8976	0/8956	0/8945	0/8943	0/8940	0/8940	0/8940
DMU11	1/0000	1/0000	0/9771	0/9505	0/9172	0/9161	0/9150	0/9142	0/9133	0/9129	0/9127
DMU16	1/0000	1/0000	0/9934	0/9822	0/9812	0/9811	0/9810	0/9792	0/9783	0/9780	0/9778
DMU19	0/9839	0/9575	0/8860	0/8789	0/8775	0/8763	0/8762	0/8742	0/8732	0/8727	0/8724
DMU32	1/0000	0/9950	0/9759	0/9646	0/9630	0/9625	0/9625	0/9624	0/9624	0/9623	0/9621
DMU38	1/0000	1/0000	1/0000	0/9868	0/9717	0/9708	0/9706	0/9705	0/9704	0/9704	0/9703
DMU40	1/0000	0/9423	0/9229	0/9037	0/9026	0/9016	0/9009	0/9002	0/8995	0/8992	0/8990
DMU42	1/0000	0/9848	0/9529	0/9285	0/9271	0/9259	0/9249	0/9239	0/9231	0/9227	0/9223
DMU47	1/0000	1/0000	0/9921	0/9911	0/9886	0/9885	0/9880	0/9871	0/9863	0/9859	0/9856

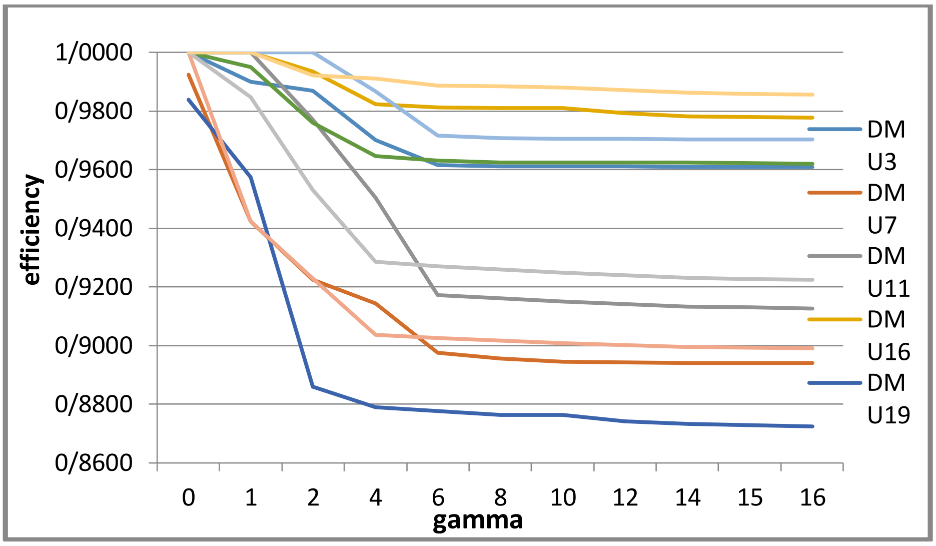

Figure ۳, the efficiencies of some DMUs for different Γs

In such cases, many analysts allow a decision maker to use his or her preferences in selecting a suitable Gamma. We utilize a graphical presentation of the results enhanced with a Monte-Carlo simulation to provide additional insight for making a final decision about Gamma and the overall rankings of the DMUs. For each input and output of DMUs, a number is randomly generated by using simulation, and by the resulting weights from $\sum_{r=1}^{s} u_r y U_{ro} / \sum_{i=1}^{m} v_i x_{io}$. Efficiencies of DMUs are recalculated and ranked again. The conformity value between the rankings resulting from the mathematical model and the simulations is computed. This results in two overall rankings for the DMUs, one from the mathematical model and another from the simulation. For example, if DMU 1 is ranked first in both rankings from model 1 and simulation, we assign a 1 to this simulation run, otherwise, we assign a 0. We repeat this procedure for each Gamma 1000 times and calculate the percent of conformity for each DMU and for each Gamma. The conformities values are presented in Fig.٤. As is shown in this Figure, the maximum conformity occurs in [6, 8] for Γ Therefore, we can conclude that specific values of Γ can maximize conformity and thus more authentic final rankings for the DMUs in this interval of Γ may be expected.

Table 5, the average conformity for different Gamma

Gamma	0	1	2	4	6	8	10	12	14	16
Conformity	0/4173	0/4964	0/5145	0/5645	0/6586	0/6589	0/5327	0/5134	0/5134	0/5036

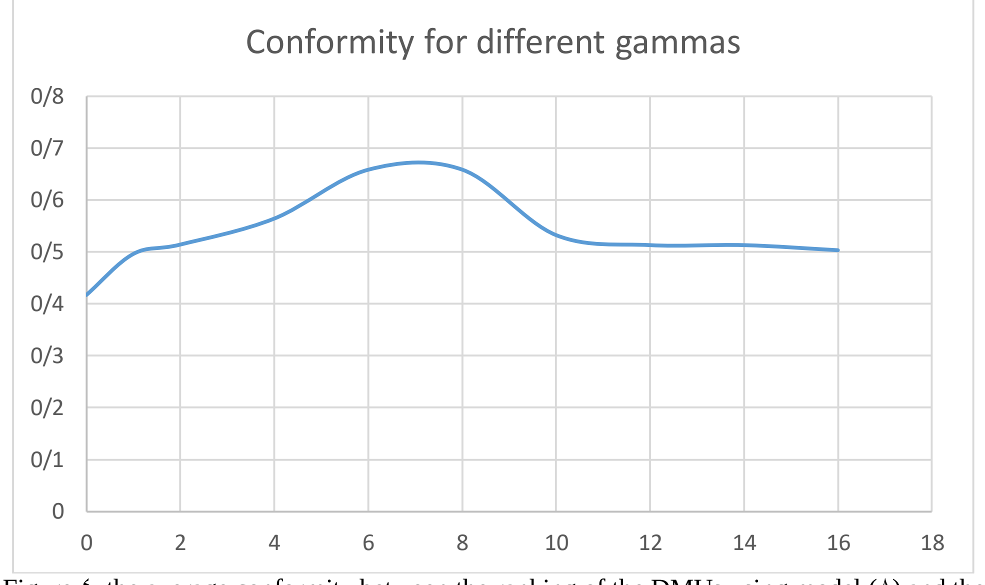

Figure ٤, the average conformity between the ranking of the DMUs using model (٨) and the simulation runs for different Gamma

The robust DEA method proposed in this study provides an alternative approach to interval and fuzzy DEA. A comparison between RDEA and IDEA reveals that the IDEA is a special case of RDEA. Interval DEA evaluate the performance of the DMUs based on the lower and upper bounds of the efficiency and RDEA provides a number between these two bounds as the efficiency of DMUs. Despotis and Smirlis proposed three classifications for interval efficiencies of the DMUs (Despotis and Smirlis, 2002; pp.24–36) as follows:

E^{++}= DMUs of which the lower efficiency scores are equal to unity
E^{+}= DMUs of which the lower efficiency scores are smaller than unity and their upper efficiency scores are equal to unity
E^{-}= DMUs of which the upper efficiency scores are equal to unity
According to the mentioned method ,and also the robust optimization method proposed in this study, the sample units investigated in this study are classified and ranked as follow:

Table6- classifying and ranking sample units According to the Despotis and Smirlis and RDEA

Units	efficiency(max)	efficiency(min)	efficiency by RDEA Γ=6	efficiency by RDEA Γ=8	Classification	Ranking Γ=6 or 8
DMU3	1/0000	0/96099	0/9616	0/9612	E^{+}	5
DMU7	0/9924	0/894012117	0/8976	0/895645476	E^{-}	9
DMU11	1/0000	0/912677445	0/9172	0/916055399	E^{+}	7
DMU16	1/0000	0/977791929	0/9812	0/9811	E^{+}	2
DMU19	0/9839	0/872386737	0/8775	0/876330673	E^{-}	10
DMU32	1/0000	0/962104037	0/9630	0/962513729	E^{+}	4
DMU38	1/0000	0/970310329	0/9717	0/970776543	E^{+}	3
DMU40	1/0000	0/898979559	0/9026	0/901635163	E^{+}	8
DMU42	1/0000	0/922346187	0/9271	0/925947655	E^{+}	6
DMU47	1/0000	0/985551218	0/9886	0/988476643	E^{+}	1

Table 6 shows that, when there is less protection for the technical efficiency models(Γ = 0), the efficiencies of the DMUs are similar to the upper efficiency reported by Despotis and Smirlis .When there is more protection for the technical efficiency model (Γ = 16), the efficiencies from the RDEA approach are similar to the lower efficiencies reported by Despotis and Smirlis . Using RDEA, a decision maker can study the rankings of the DMUs for each gamma and determine which DMUs are sensitive to changes in the data. The table above shows units have been ranked, with taking Γ = 8. The fuzzy DEA deals with data expressed in linguistic form and usually use the alpha-cut approach to transform the model into a binary model. With this alteration, lower and upper bound efficiencies are calculated for each alpha and the fuzzy DEA approach has the same feature as the interval DEA.

6- Conclusions

In this study a pattern has been proposed to evaluate efficiency of organizations in performing EFQM MODEL using Robust DEA model with the following features:

- Inputs and outputs are based on RADAR logic in the EFQM model.
- There are 60 DMUs under study with 3 inputs and 17outputs. All of Inputs and also one of outputs are certain values and 16 outputs related to the enablers are in form of intervals with uncertain bounds.
- Some data are imprecise, hence, we deal with a type of interval data with vague bounds.
- The performance evaluation based on the mathematical optimization rules has been replaced by the current multi-criteria evaluation approach.

In the conventional DEA, all the data are certain numerical values. But, values of 16 output data in in this study are uncertain. The uncertain or imprecise data in the DEA models have been reviewed in the literature in different ways. The exclusion of the units with imprecise values from the analysis, the imputation methods to estimate the approximations of the imprecise values and the stochastic approach are among the methods most commonly used to model uncertainty in the DEA literature. Recently, the interval DEA and the fuzzy DEA are used to deal with the imprecise data in DEA. The contribution of this study is threefold :(1) we consider uncertain and imprecise output data and implement the proposed framework in the real-world(to evaluate efficiency of organizations in performing EFQM model) ; (2) we propose a robust optimization DEA model in which the output parameters are in form of intervals with uncertain bounds ; and (3) we use randomly a set of numbers generated for each input and output of DMUs to specify a range of Gamma in which the rankings of the DMUs occur with high probability and then compute the conformity of the rankings resulting from the mathematical model with reality.

as a further matter, use of this model for evaluating of organizations has useful elements such as the possibility to consider views of experts, comprehensiveness of indices, adjustment with RADAR logic in EFQM model and its criteria and concepts, and lack of existing conflicts in the current assessment system. The important aim which is pursued in this research is the survey for omitting deficiencies of organization by having successful models than rest of organizations. An important topic is emphasized in the assessment logic with excellence model, for which no certain executive mechanism has been predicted. This research shows that the used model smooths the way for such possibility for inefficient units. Detection of reference units in data envelopment analysis specifies the most accessible models for each of organizations. Assessment logic in the current assessment system has not possibility for transparency in this context. Yet, use of input-based models of data envelopment analysis provides such doubts and clarifies difference in each inefficient organization with reference organizations by comparing outputs. Another point lies on existing flexibility in the proposed model. Parameter Γ in the proposed model provides this flexibility. In the other hand, increasing value of Γ can raise sufficient trust to consider all the assessments by the assessors. Hence we can use this parameter as a regulating parameter to build balance in this context. An interesting point lies on this fact that most of organizations especially public organizations fail to select values for input variables such as budget, number of staffs and/or education level of staffs and enjoy restricted authorities in this context, thus they introduce the existing difference in these elements compared to the rest of organizations.

References

[1] Bolboli.S.A, "Introducing a concept for efficient design of EFQM excellence model," *TQM Journa,* pp. pp.382-396, 2015.

[2] Semnani.F and R. Asadi, "Designing a Developed Balanced Score-card Model to Assess Hospital Performance Using the EFQM, JCI Accreditation Standards and Clinical Governance," *Journal of Business and Human Resource Management,* pp. Volume 2, Issue 1, 2016.

[3] Dickel.D.G. and G. Moura , "Organizational performance evaluation in intangible criteria: a model based on knowledge management and innovation management," *RAI Revista de Administração e Inovação,* pp. 211-220, 2016.

[4] A. Neely, Gregory and Plants, K., "performance measurement system design," *International Journal of Operations and Production Management,* pp. 80-116, 1995.

[5] R. Simons, performance Control and measurement systems for implementing the strategy, Ariana industrial research group, 2000.

[6] J. Hale, performance based management: what every manager should do to get result, New York : John Wiley & Sons., 2004.

[7] T. Karimi, " The novel models of organizational performance evaluation," *journal of management,* vol. 171, 2006.

[8] E. Jafarpour1, N. Mollaverdi, F. MokhatabRafiei and M. Arabzad, ". (2012), "Evaluation of the Suggestions System Performance Using DEA.,," *J. Basic Appl. Sci. Res,* vol. 2, no. 11, pp. 11717-11725, 2012.

[9] e. a. Hadi, "Performance Evaluation of the Suggestion System," *DOI: 10.5455/ Med Arh,* vol. 67, no. 2, pp. 131-133, 2013.

[10] T. R.G., T. R.M., S. F.D. and B. Smith, "Comparative Site Evaluations for Locating a High-Energy Physics Lab in Texas," *Interfaces,* vol. 16, pp. 35-49, 1986.

[11] P. Brockett, A. Charnes, W. Cooper, Z. Huang and D. Sun, "Data Transformation in DEA Con Ratio Envelopment Approaches for Monitoring Bank Performance," *European Journal of Operational Research,* vol. 98, pp. 250-268, 1997.

[12] W. Cooper, . L. Seiford and K. Tone , Data Envelopment Analysis; A Comprehensive Text With Models , Applications, References and DEA, Springer US,DOI: 10.1007/978-0-387-45283-8, 2000.

[13] W. W. Cooper, K. S. Park and . G. Yu, "IDEA and AR-IDEA: Models for dealing with imprecise data in DEA," *Management Science,* vol. 45, p. 597– 607, 1999.

[14] D. K. Despotis and . Y. G. Smirlis, "Data envelopment analysis with imprecise data," *European Journal of Operational Research,* vol. 140, p. 24–36, 2002.

[15] P. Guo and H. Tanaka, "Fuzzy DEA: A perceptual evaluation method," *Fuzzy Sets and Systems,* vol. 119, p. 149–160, 2001.

[16] E. Nasrabadi, M. Soleimani damaneh and G. jahanshahloo, "Measure of efficiency inDEA with fuzzy input-output

levels," *Applied mathematics and camputation*, vol. 1, pp. 175-187, 2004.

[17] P. Guo,, "Fuzzy data envelopment analysis and its application to location problems," *Information Sciences*, vol. 179, p. 820–829, 2009.

[18] A. Azadeh, . S. Ghaderi, . Z. Javaheri and . M. Saberi, "A fuzzy mathematical programming approach to DEA models," *American Journal of Applied Sciences*, vol. 5, no. 10, p. 1352–1357, 2008.

[19] A. Shokouhi, . A. Hatami-Marbini and M. Tavana , "A robust optimization approach for imprecise data envelopment analysis," *Computers & Industrial Engineering*, vol. 59, p. 387–397, 2010.

[20] H. Nikfarjam , Hava, M. Rostamy-Malkhalifeh and A. Noura, "A New Robust Dynamic Data Envlopment Analysis Approach for," *Advances in Operations Research*, vol. 2018, 2018.

[21] R. shakouri , m. salahi and s. kordrostami, "Stochastic p-robust DEA efficiency scores approach to banking sector," *Journal of Modelling in Management*, vol. 15, no. 3, 2020.